# Mineral Development in Ontario North of 50°

Technical Paper #7

## Molybdenum

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the ROYAL COMMISSION on the NORTHERN ENVIRONMENT

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## INTRODUCTION

The purpose of this chapter is to show that there is plenty of molybdenum in the world, especially in the United States and Canada, though little is found in Ontario, and that in the face of the expected continued rise of world molybdenum consumption, there is no world shortage foreseen for a long time, especially since huge sums are invested to assure the availability of these needed supplies in the future from the relative abundance of this resource. However, difficulties exist in predicting adequately the behaviour of molybdenum prices in spite of the fact that they are certain to rise steadily during this decade mainly due to increasing costs of both production and delivery to the market from remote mines.

This discussion is organized in the following manner. The basic properties, qualities, uses and substitutes of the metal are very briefly outlined in the first section. The usefulness of the metal as an industrial input is carefully explored in the second section with special reference to its main end-uses in the United States and in other important industrialized countries of the world.

The production of molybdenum in the world, Canada and Ontario is studied in Section III, which also touches upon the main world producers and upon Canada as an exporter of the metal. Section IV studies the problems of world molybdenum reserves

and their distribution, and, afterwards, it examines investment and other molybdenum-mining and related activities in countries holding considerable molybdenum deposits. The last section raises the view towards the future of both molybdenum prices and production to be followed by a final summary of the high-lights of the analysis and by drawing some conclusions.

## SECTION I: THE METAL

### Molybdenum: The Metal

Molybdenum is a metallic element of the chromium group. It resembles iron with its white colour, has a similar malleability, does not fuse easily and it has the capacity for forming steel-like alloys with carbon. An important chemical compound of molybdenum is molybdenite. This is molybdenum disulfide, $M_oS_2$, which finds various important applications.

Molybdenum occurs in two forms: one, as the chief metal sulfide in large low grade porphyry molybdenum deposits and two, as a minor sulfide in low grade porphyry copper deposits. It is found mainly in North America and the west coast of South America. The Asian continent including Russia accounts for most of the remainder of known world deposits.

Substitution for molybdenum as an alloy may occur in steels, cast irons, and other, non-ferrous metals. Although the metal industries have been keen in developing new materials which utilize the alloying properties of molybdenum, there are a number of potential substitutes. In the field of steel alloys, chromium, vanadium, columbium, and boron could serve a similar purpose. Tungsten could replace molybdenum in tool steels while graphite, tungsten and tantalum would be applied in the

production of refractory materials in high-temperature electric furnaces. In the area of pigments, molybdenum orange has substitutes in chrome orange and cadmium red as well as in natural, organic pigments.

## SECTION II: CONSUMPTION ASPECTS

### Industrial Uses

This section studies the sectors of consumption of molybdenum, the metal which Alexander Sutulov, its scientific world authority, calls "a 20th century metal."[2] No question, molybdenum has a fascinating history and our task is to review its recent development. The view is focussed briefly on the specific end-uses which it serves with the purpose to recognize that this metal does not only reflect that a country is on the road towards industrialization - as was the case with lead and zinc - but that a country utilizing this metal extensively has arrived at, or is rapidly heading for, a high level of industrialization. Molybdenum is used in areas of high-technology as modern technological progress exerts ever-increasing demands on materials than was formerly the case. At one time, for instance, small diameter pipelines were required, whereas now, large diameter, high pressure pipes with relatively thin walls are necessary. Thus, as molybdenum is importantly linked to the supply of energy, it is also needed in transportation equipment, in the chemical industry, in the electrical field and in food processing.

### Energy

Today, oil and gas sources are found mainly by drilling deeper into the earth's crust. In the process, and especially below a depth of two and a half miles, specialty steels alloyed

with molybdenum have to be used to fence off the corrosive chemical agents of hydrogen sulfide, carbon dioxide and brine.

Yield-increasing methods in oil and gas recoveries utilizing high-temperature processes such as injected steam and in-situ burning, particularly in the presence of corrosive chemical agents, demand stainless molybdenum steels and alloys. Another factor which adds to the demand is the remoteness of these energy resources from the markets to which they have to be brought. These distribution systems demand high-quality, high-pressure-wall gas and oil pipelines which, in many cases, have to withstand extreme climatical conditions.

Conventional fossil-fuel plants use pipes and steels containing molybdenum. Synfuel processing plants require non-corrosive, high-temperature, high-pressure pipes and vessels made of steel alloyed with molybdenum and chromium. Molybdenum steels find also application in the field of pollution controls. Scrubbers in coal-fired thermal power plants are made of molybdenum as they serve to desulphurize gases. Anti-pollution equipment in the pulp and paper industry will increasingly absorb molybdenum while the metal is also conveniently used for power plants working with sea-water heat exchangers.

In the nuclear industry, the metal fast breeder system demands chromium-molybdenum steels which can withstand high temperatures. In the future, fusion reactors will likewise

use high-temperature steels as the entire nuclear power systems will have to rely on steel alloys containing fairly large percentages of this metal. The construction industry also uses the metal. It is found in solar collectors, hot-water heating systems, super heaters, heat exchangers and specialty structural steels.

Transportation

In the field of transportation, high molybdenum carburized steels are found in front-wheel driven cars, while ductile iron alloyed molybdenum-cum-silicon dual-phased steels are very serviceable for high-strength, weight-reducing, cold-formed auto parts such as wheels and bumpers. The turbo-charged passenger car will require molybdenum-steel parts in the engine just like diesel engines. It is needed for cylinder heads, manifolds, valves and valve seals to guarantee a larger engine life. High-purity molybdenum is also an ingredient in long-life lubricants in gears and it is added to motor oils. Another transportation area in which the role of molybdenum finds increasing use is the railroads. Chromium-molybdenum, high-strength rails make it possible to carry heavier loads. The metal has become an important component in the cast-iron couplings which have to withstand substantial stress and friction.

In the field of aviation, no modern airplane, military or commercial, is thinkable without high-temperature, super-molybdenum alloys of many of its components. To this application

has to be added the eutectic molybdenum superalloys which use between 18 and 37 percent of the metal.

## Other Industries

Besides being a refractory material, molybdenum has other uses in the chemical industries. It is needed for the cracking and reforming of oils as it functions as a catalyst. It enters the field of pigments especially in paint primers. Furthermore, it is a laboratory reagent and needed in the ceramics industry and in various other chemical processes.

In the area of electricity and electronics, molybdenum should not be forgotten. It provides electric heating elements for electric furnaces, and molybdenum is contained in electrical contacts, electrodes, anodes, power transistors and in semi-conductor devices such as power and control rectifiers.

Finally, there is the food sector. It is the food processing industry which requires non-corrosive materials and equipment. Again, molybdenum comes into its own finding appropriate applications, be it in butcher knives or in the machinery of the canning industry.

## Pattern of Molybdenum Consumption

### United States

The United States represents a country at a high level of technology. Its use-pattern of molybdenum is therefore a fair reflection of the high technological needs which this

metal satisfies. There are at first the different molybdenum products which serve as such inputs. They are: molybdic oxides, ferro molybdenum, ammonium and sodium molybdates and other molybdenum products such as molybdenum disulfide, molybdenite concentrates, as well as powders and pellets. The quantities and their distribution by type of input in the United States for the years 1977 and 1979 are given in the four double columns of Table 1; the fifth and last double column presents the total consumption of all types of molybdenum materials and their distribution.

Molybdic oxides are the most important molybdenum input materials. They account for about 68 - 71 percent of the total used. Ferro molybdenum is second in importance, counting between 13.5 and 17.3 percent of the total. Both types are of critical importance for steel, cast iron and superalloys. Other molybdenum materials, (4) rank third in importance and find application in powder mill products. Ammonium and sodium molybdates are the smallest of these four component groups. Yet, their significance in the chemical industries cannot be underestimated as they are absorbed as pigments and catalysts.

In total (5), it is apparent that about 68 percent of all molybdenum materials enter into the production of alloyed and stainless steels, with cast irons and superalloys following next in line. Here, the 1979 values appear to display a much larger use in superalloys than in 1977. Molybdenum powder marks

Table 1

Pattern of Molybdenum Consumption by Type of End Uses in the United States for the Years 1977 and 1979

(Totals in pounds)

| Total Inputs of Molybdenum Products | (1) Molybdic Oxides | | (2) Ferro Molybdenum | | (3) Ammonium & Sodium Molybdate | | (4) Other[1] Molybdenum Materials | | (5) Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| Years | 1977 | 1979 | 1977 | 1979 | 1977 | 1979 | 1977 | 1979 | 1977 | 1979 |
| Total in '000 pounds | 34133 | 40627 | 8735 | 7756 | 1011 | 738 | 6569 | 8288 | 50448 | 57409 |
| End Uses in percent | % | % | % | % | % | % | % | % | % | % |
| Steel | 86.5 | 86.4 | 46.0 | 52.7 | - | - | 5.6 | 3.0 | 67.2 | 68.7 |
| Cast Irons | 2.3 | 1.2 | 38.4 | 29.5 | - | - | 2.2 | 2.7 | 8.5 | 5.3 |
| Superalloys | 3.6 | 4.8 | 3.3 | 5.0 | - | - | 18.6 | 27.9 | 5.4 | 8.1 |
| Alloys | 0.3 | 0.2 | 10.6 | 10.9 | - | - | 2.3 | 2.1 | 2.3 | 1.9 |
| Millproducts powderbase | - | - | - | - | - | - | 50.0 | 51.2 | 6.6 | 7.4 |
| Chemicals and Ceramics | | | | | | | | | | |
| Pigments | 1.9 | 1.1 | - | - | 59.2 | 34.6 | 0.1 | - | 2.5 | 1.2 |
| Catalysts | 4.5 | 5.4 | - | - | 31.7 | e) | - | - | 3.7 | 3.8 |
| Other | 0.2 | 0.0 | 0.3 | - | 3.4 | | 14.6 | 8.3 | 2.2 | 1.2 |
| Misc. & unspecified | 0.6 | 0.9 | 1.4 | 1.8 | 5.7 | 65.4 | 6.6 | 4.7 | 1.6 | 2.4 |
| Subtotal | 99.9 | 100.0 | 100.0 | 99.9 | 100.0 | 100.0 | 100.0 | 99.9 | 100.0 | 100.0 |
| % of Total | 67.7 | 70.8 | 17.3 | 13.5 | 2.0 | 1.3 | 13.0 | 14.4 | 100.0 | 100.0 |
| Stocks | 20.4 | 12.0 | 17.2 | 20.3 | 18.1 | 37.3 | 18.8 | 19.1 | 19.6 | 14.4 |

Source: ABMS, Non-ferrous Metal Data, 1977 and 1979, New York, N.Y.

[1] Includes purified molybdenum disulfide, molybdenite concentrate added directly to steel, molybdenum metal powder and pellets, and other molybdenum materials.

[e] information witheld.

the fourth important use category while catalysts are definitely the most significant items among absorption of molybdenum mainly by the chemical industry.

It is very worth noting that this pattern of consumption has not undergone any substantial change over a relatively long period of time. For instance, the use-pattern in 1962 is almost the same as for the years 1977 and 1979. The breakdown is as follows:

Estimated Uses of Molybdenum in the U.S. in 1962

| | |
|---|---|
| Alloy steel (other than stainless and tool steels) | 47% |
| Stainless steel | 13% |
| Tool steel (including high-speed steel) | 8% |
| Cast iron (other than steel-mill rolls) | 8% |
| Molybdenum metal | 6% |
| Pigments and catalysts | 5% |
| High-temperature alloys | 4% |
| Steel-mill rolls | 4% |
| Miscellaneous | 5% |
| | 100% |

Source: See 5

When the first three itmes are added, it shows that the molybdenum used for steel products amounts to 68%, which is the same distribution value as noticed for the year 1979. Only small variations occur among alloys and superalloys while molybdenum pigments and catalysts are absorbed to the same degree now as they were then, pointing to the conclusion that, in the U.S.A., the use-pattern over time has been a very stable one.

World Use

Within the confines of the Western World, the use-pattern conforms quite well to that recorded for the United States. The following breakdown demonstrates this fact:

Consumption of Molybdenum in non-communist countries by major industrial categories for the year 1979

| | |
|---|---|
| Alloy steels | 47% |
| Stainless steels | 20% |
| Tool steels | 9% |
| Cast iron and steel mill rolls | 7% |
| Super and special alloys | 3% |
| Molybdenum metal | 4% |
| Chemicals | 9% |
| Other | 1% |
| | 100% |

Source: See 4

The importance of alloy and stainless steels is highly similar to that of the United States. If any difference exists, then it is to be found with respect to the superalloys which have a much higher profile in the United States. In turn, the chemical use of molybdenum must be more pronounced outside the United States. It has to be born in mind that the United States are included in the above tabulation accounting for 38 percent of the consumption of this metal in the Western World.[5] In this comparison, it has also to be recognized that Western Europe carries a greater weight because its industrial users together consume more molybdenum than the United States. In short, the United States displayed a relatively stable pattern of consumption over time and, at present, it would appear that the remainder of the industrialized Western World does not deviate essentially from that input picture.

## SECTION III: MOLYBDENUM PRODUCTION

Molybdenum is one of the few metals in the world which, in its consumption, especially over the recent years, was severely limited by the available supplies. Inventories remained low and even the strategic stockpile of the United States was depleted. In Canada, allocation schemes were implemented and tariff remission granted to equitably solve the problem of molybdenum shortage for all users.[6] This extremely tight world supply situation was aggravated by strikes in the molybdenum mines in British Columbia during the year 1979.[7]

Due to these exceptional circumstances of a restrained consumption in face of limited supplies - a condition which was observed for the majority of the years under investigation - it is theoretically valid to equate the total of consumption with the available supplies of mined molybdenum. Going one step further, it can be argued that the apparent equality between consumption of the metal and its mineral supplies may be extended quite validly to include the demand for the mined metal. However, it has to be born in mind that the potential consumption could have been larger during most of these years.

Therefore: potential molybdenum consumption = actual consumption = demand production of molybdenum.

This simply means that, so far, actual consumption equalled supply in a way that the industry did not experience positive inventory problems barring minor temporary exceptions. This demand pressure was exerted by economic growth combined with technological progress producing the following spectacular production scenario.

World Production of Molybdenum

World production of molybdenum in the year 1950 was 14,230 metric tons. By 1979, it had reached 103,066 metric tons, which means an (annual) addition of 624 percent or an increase by a factor of more than seven times over the earlier value. This performance is set out in Table 2. It makes further comments unnecessary!

Canada and Ontario

In the year 1950, Canada was a small and insignificant producer of the metal as a total of 28 metric tons were mined.[8] By 1951, 104 metric tons of molybdenum were extracted. Slowly, annual output rose to 205 metric tons in 1954. In the following year, it reached 378 metric tons and it stayed around this level until 1963. From then on, the picture changed abruptly. In the year 1964, the level of Canadian molybdenum production rose to 556 metric tons to jump to 4,335 metric tons in the next year.

Table 2

World and Canadian Output of Molybdenum

Canada's and Ontario's Shares as World Producers

for the Years 1950 to 1979

| Year | Metric Tons World | Metric Tons Canada | Canada Share in World Output % | Ontario Share in World Output % |
|---|---|---|---|---|
| 1950 | 14230 | 28 | 0.2 | 0.0 |
| 1951 | 19980 | 104 | 0.5 | 0.0 |
| 1952 | 21650 | 138 | 0.6 | 0.0 |
| 1953 | 27760 | 88 | 0.3 | 0.0 |
| 1954 | 28400 | 205 | 0.7 | 0.0 |
| 1955 | 30100 | 378 | 1.3 | 0.0 |
| 1956 | 28310 | 382 | 1.3 | 0.0 |
| 1957[2] | 33970 | 355 | 1.0 | 0.0 |
| 1958 | 25190 | 403 | 1.6 | 0.0 |
| 1959 | 30380 | 340 | 1.1 | 0.0 |
| 1960 | 40410 | 348 | 0.9 | 0.0 |
| 1961 | 40030 | 350 | 0.9 | 0.0 |
| 1962 | 34140 | 371 | 1.1 | 0.0 |
| 1963 | 41250 | 378 | 0.9 | 0.0 |
| 1964 | 42850 | 556 | 1.3 | 0.0[3] |
| 1965 | 52390 | 4335 | 8.3 | 0.0 |
| 1966 | 64660 | 9342 | 14.4 | 0.0 |
| 1967 | 65290 | 9696 | 14.8 | 0.0 |
| 1968 | 67270 | 10190 | 15.1 | 0.0 |
| 1969 | 74630 | 13450 | 18.0 | 0.0 |
| 1970 | 83500 | 15319 | 18.3 | 0.0 |
| 1971 | 78770 | 10279 | 13.0 | 0.0 |
| 1972 | 82030 | 12924 | 15.7 | 0.0 |
| 1973 | 83500 | 13786 | 16.5 | 0.0 |
| 1974 | 87020 | 13942 | 16.0 | 0.0 |
| 1975 | 82610 | 13026 | 15.8 | 0.0 |
| 1976 | 89510 | 14618 | 16.3 | 0.0 |
| 1977 | 95200 | 16431 | 17.3 | 0.0 |
| 1978 | 99719 | 14068 | 14.1 | 0.0 |
| 1979 | 103066 | 11187 | 10.9 | 0.0 |

Source: United Nations. Statistical Yearbooks, New York, N.Y.

The main producing provinces are Quebec (1950-1979), British Columbia (196401979): see Table Metal 5, Technical Information Paper No. 2, of this study, p. 9-10.

2 including U.S.S.R. 1957 -

3 In 1964, Ontario produced 5.17 metric tons of molybdenum, which is insignificant by world standards.

By 1966, the record shows 9342 metric tons produced. After 1968, it never fell below the 10,000 metric ton mark. A minimum of 16,431 metric tons was extracted in the year 1977, but output receded in the subsequent years due to the strikes in the molybdenum mines in British Columbia. Output fell to 11,187 metric tons for the year 1979, a decline of 32 percent over the 1977 production peak.[9]

Table 2 tells how Canada became a world producer. From a relatively unimportant position in the molybdenum scene in the 1950s and early 1960s, this country emerged to become the second largest producer in the world, indeed! During all these years, Ontario did not play any role at all. This does not mean that there are no molybdenum deposits in the Province. Quite to the contrary, they do exist[10] and some molybdenum was produced in Ontario with some important contributions made during World War I.[11] Yet, the main Canadian producer until 1961 has been, without doubt, the Province of Quebec.[12] Today, British Columbia is the main Canadian supplier of this metal.[13]

## Main World Producers

The world's largest producer of molybdenum has been and still is the United States of America. This is clearly brought out in Table 3. In the years 1950 and 1955 - two years which exclude the molybdenum production of the U.S.S.R. - the United

States produced over 90 percent of the world's total. The second largest producer was Chile, followed then already by Canada. During the succeeding five-year periods, the scene changed considerably in Canada's favour and by 1975, this country had become the second most important source of molybdenum for the world. It was followed by Chile and the Soviet Union, both tied for third place with 11.1 percent each. This pattern of the distribution of production was altered somewhat as Canada moved temporarily to a lower rank with strikes plaguing this part of the Canadian mining industry.

Table 3

Percentage Distribution of World Production of Molybdenum by Main Producing Country for Selected Years between 1950 and 1979

| World Output in metric tons | 1950 14230 | 1955 30100 | 1960 40410 | 1965 52390 | 1970 83500 | 1975 82610 | 1979 103066 |
|---|---|---|---|---|---|---|---|
| Canada | 0.2 | 1.3 | 0.9 | 8.3 | 18.3 | 15.8 | 10.9 |
| Chile | 7.0 | 4.2 | 4.6 | 7.1 | 6.8 | 11.0 | 13.2 |
| China | - | - | 3.7 | 2.9 | 1.7 | 1.8 | 1.5 |
| Peru | - | - | - | 1.3 | 1.2 | 0.9 | 0.9 |
| Sweden | - | | | | - | 0.6 | - |
| U.S.S.R. | ? | ? | 12.4 | 11.8 | 9.2 | 11.0 | 9.7 |
| U.S.A. | 90.8 | 93.0 | 76.6 | 67.0 | 60.5 | 58.2 | 63.4 |
| | 98.0 | 98.5 | 98.2 | 98.4 | 97.7 | 99.3 | 99.6 |

Source: United Nations Statistical Yearbooks, New York, N.Y. Additional information for 1979 was obtained from the Statistical Office of the Secretariat-General of the U.N.

At this point, it is also of interest to note that the U.S.S.R., which has made ever-increasing inroads into the production of the metal, does not appear to be able to push further ahead. This observation follows from the available production estimates for that country. If these figures are correct, it would mean that the U.S.S.R., at best, is expanding its molybdenum recovery at the same rate as the world in general and not faster. A scarcity of such resources may explain this for the U.S.S.R.'s unusual behaviour when compared with most of the other metals under study in which the U.S.S.R. outproduced any other country.

## Canadian Molybdenum Exports

Canada is a net exporter of molybdenum. These exports take the form of ores and concentrates and, as shown in Table 4, they match very closely the total of Canada's mine production (Table 2). Canada's main customer countries are Belgium, Japan, the United Kingdom, the United States and Western Germany. Of these, the most important have been in recent years, Belgium and Japan. Furthermore, it is again an interesting observation that, in 1979, 1.6 percent of our molybdenum exports went to the Soviet Union.

On account of the relatively large exports which, in some of these recent years, were greater than our mining output, it would appear inconceivable how Canada could use molybdenum as

inputs, especially in its steel plants. A brief glance at a Canadian consumption and production picture can tell the tale.

| | | metric tons | | Imports | |
|---|---|---|---|---|---|
| Year | Production | Exports | Consumption | Molybdenum Oxide | Ferro-Molybdenum |
| 1979 | 11,187 | 11,483 | n.a. | n.a. | n.a. |
| 1978 | 14,098 | 15,143 | n.a. | 330 | 55 |
| 1977 | 16,431 | 15,310 | 928 | 192 | 74 |

Obviously, Canada exports so much of its ores and concentrates that it would not have enough for its own consumption. For this reason, imports are needed and they come from the United States in the form of molybdenum oxide and ferro-molybdenum. Unfortunately, Statistics Canada does not publish detailed figures in this respect and most of the sources consulted had to rely upon the trade statistics of the United States.[14] It is actually surprising to find that for the year 1977, 266 metric tons of molybdenum were imported, amounting to 28.6 percent of Canada's consumption - assuming that these imports would have been used up in the same year - yet, this reliance on foreign sources for molybdenum inputs in a more refined form is nothing new. It is symptomatic of the Canadian trade picture. Ores and concentrates are shipped to other countries from whom we reimport the metal in a higher state of refinement. Molybdenum goes to the United States, and in turn, the oxide comes back to us. It would not

Table 4

Molybdenum in Ores, Concentrates and Scrap (commodity 259-50)

| | Quantity metric tons | Value $'000 |
|---|---|---|
| Year | Exports | Exports |
| 1979 | 11,483 | 250,917 |
| 1978 | 15,143 | 137,053 |
| 1977 | 15,310 | 125,594 |

| | | | |
|---|---|---|---|
| Exports | 1977 | Bel-Lux | 38% |
| | | Japan | 26% |
| | | U.K. | 15% |
| | | U.S. | 8% |
| | | W. Germany | 7% |
| | 1978 | Japan | 28% |
| | | Bel-Lux | 28% |
| | | U.S. | 22% |
| | | U.K. | 11% |
| | 1979 | Bel-Lux | 25% |
| | | Japan | 20% |
| | | U.K. | 17% |
| | | W. Germany | 16% |
| | | U.S. | 10% |

In 1979, the U.S.S.R. received 1.6% of our molybdenum ore, etc.

1978: U.S.S.R. 357/15143

1977: U.S.S.R.

be difficult to show that a considerable amount of our exported ores and concentrates, when in the hands of our customers, are not only used for industrial production, but are re-exported in refined form!

This is not a new phenomenon. As early as 1947, huge quantities of these molybdenum products have been imported into Canada for domestic consumption, a fact which applies to any year thereafter! Unfortunately, it is not possible here to make an exact comparison, due to certain differences in the standards of measure.

One thing is again certain: Canada, a major producer of molybdenum ores and concentrates of the world, does not refine all the molybdenum for its home consumption. It leaves it to its foreign customers who refine the raw material.

## SECTION IV: WORLD RESERVES AND ALTERNATE SUPPLIERS

This section discusses, at first, the geographical occurrences, magnitude and distribution of molybdenum mineral and ore deposits and, afterwards, it examines the investment activities and production potentials of the metal in the most important supplying countries.

### Molybdenum Reserves

The general mineral occurrences of molybdenum in the earth's crust places the metal between silver and lead. In the first outer kilometer of that continental crust, the probability factor of 2.50 ppm would give a total of 990,000,000,000 tons of molybdenum. This is the probable metal content as stated by M.G. Fleming.[16] The actual ores and potential ores of interest in the context of this study are largely embedded in porphyry-type ore bodies in which molybdenum is counted as the main product. In other polymetal deposits, it is a by-product, especially of copper. The main deposits of the porphyry variety are unevenly distributed thoughout the world. They are chiefly located in the Rocky Mountains of North America and the Andes of South America. That is why the molybdenum production is concentrated in the Americas.

Table 5 gives two different estimates. The smaller one - short-run reserves - should be seen as the immediately available, economic reserves, whereas the larger of the two figures - the long-run reserves - includes all deposits which at one time may become economic. Again, great caution has to be taken not to read too much into these reserve estimates!

Nonetheless, the distribution of these reserves is of great interest, since they display the indisputable predominance of the United States, especially when seen over the long run. One State of the Union alone holds almost 32 percent of the world total of molybdenum deposits. This is the State of Colorado; it is followed by New Mexico (12.7%) and Arizona. In this context, the United States accounts for 55.6 percent of world molybdenum reserves. Canada is in second place with 15.8 percent, followed by Chile with 8.7 percent. The U.S.S.R. is the fourth largest reserve owner accounting for 7.9 percent of the total, at least on the base of this statistic.

In general, North and South America hold 87 percent of the world's molybdenum reserves, which is an overwhelmingly large proportion for any mineral. That is the reason why the U.S.A., Canada and Chile are so strong in the world molybdenum market, supplying metal on which many industrial countries depend.

Table 5

Identified Molybdenum Resources, World Total in metric tons

and Distribution by Country or Region

| Total Reserves: | 28,617,000 metric tons | | 9,800,000 metric tons |
|---|---|---|---|
| U.S.A. | % | % | % |
| Arizona | 3.1 | | |
| Colorado | 31.7 | | ( Of this quantity only 8530 000 mt are accounted for; 87%) |
| New Mexico | 12.7 | | |
| Other States | 8.1 | | |
| Total U.S.A. | | 55.6 | 44.9 |
| Canada | | 15.8 | 15.3 |
| Mexico | | 1.6 | 2.0 |
| Others | | 2.7 | |
| Chile | | 8.7 | 14.3 |
| Peru | | 2.1 | 4.1 |
| Other | | 0.5 | |
| U.S.S.R. | | 7.9 | 4.1 |
| Bulgaria | | 0.2 | 0.1 |
| Yugoslavia | | 1.6 | |
| Other Europe | | 0.3 | |
| Morrocco | | 0.1 | |
| Other Africa | | 0.1 | |
| China | | 1.6 | 1.0 |
| Japan | | 0.2 | 0.2 |
| Other Asia | | 0.6 | |
| Rep. Korea | | | 0.4 |
| Australia | | 0.2 | |
| Other Australasia | | 0.3 | |
| Philippines | | | 0.6 |

Source: Andrew Kuklis, Molybdenum, Mineral Facts and Problems, op. cit., p. 703.
Duncan R. Derry, A Concise World Atlas of Geology and Mineral Deposits, Mining Journal Books, London, 1980, p. 97.

<u>Alternate Suppliers</u>

United States

In the United States, four companies dominate the output of molybdenum. They account for 91 percent of total production. The most important is the AMAX Corporation with at least three mines in the United States: the Climax mine, the Urad mine and the Henderson mine as the most recent addition. They are located in Colorado. The Questa mine, operated in New Mexico, is owned by the Molybdenum Corporation.[17] These two corporations are the largest suppliers of molybdenum ores. Other corporations such as the Duval Corporation, the Duval Sierrita Corporation - both owned by Pennoil Corporation - are the main producers of molybdenum as a by-product of copper. Here, the output of molybdenum is geared to the conditions in the copper market. When copper markets were poor, closure of copper mines resulted. Examples are Esperanza Mine of Duval and Pima Mine of Cyprus Mines which were reopened in 1979 after such shutdowns were necessary in earlier years.[18] The same holds for the Anamax's Twin Buttes Mine and the San Manuel Mine of the Magma Copper Company, both in Arizona.

The United States is far ahead above other countries in the field of molybdenum production. The following investments are contemplated. The AMAX Corporation is working on the Mount Emmons property in Gunnison County in southwest Colorado.[19]

This property falls right into the Climax and Henderson geology. The ore reserve is quoted between 155 and 165 million metric tons, having an ore grade of between 0.44 and 0.43 of 1 percent. Amax expects this property to go into production in the year 1990 at a still unknown cost.

Amoco Minerals is investing $300 million with a mine at Thompson Creek, Idaho, to produce 18 million pounds (8,163.3 metric tons) per annum: with an ore reserve of 181.4 million metric tons of 0.18% of $MoS_2$, this mine will start operations in 1984.

Anaconda is investing $200 million into an open-pit operation in Nye County, Nevada, to produce 12 million pounds (5,442.2 metric tons) of molybdenum per annum, starting in 1982. The reserves are 136 million metric tons of ore with a grade of 0.096 of 1 percent.

The Molybdenum Corporation is spending $200 million on its Questa Mine to feed 16,500 metric tons of ore per day through the concentrator. The same company is spending an additional $20 million for a molybdenum plant to raise the annual capacity from 6 million pounds (or 2,721 metric tons) to 26 million pounds (or 11,791 metric tons) per annum. This project should be completed by 1983.

Another interesting project is a copper-molybdenum project on the reservation of the Colville Indians in eastern

Washington State. After an economic and environmental feasibility-cum-impact study, AMAX and the Colville Indian Community signed a lease agreement for the exploitation of this molybdenum deposit in January of 1981. The agreement is subject to approval by the Department of the Interior's Bureau of Indian Affairs. The known ore reserve is 900 million tons with a 0.1 percent of molybdenum and 0.09 percent of copper. AMAX's investment will amount to $500 million for an open-pit mine which is expected to start in the middle of the 1980s. Annual ore production will be 13.6 million metric tons. The corresponding concentrate would contain roughly 13,600 metric tons of metal.[20] This mine would have a life-expectancy of forty-three years.

Finally, there is the U.S. Borax Corporation. It has a property at Quartz Hill in Alaska, where it is planning to operate an open-pit mine to produce 36,300 metric tons per day. The planned investment is $400 million and the ore reserve 636 million metric tons with a quality of 0.154 of 1 percent in molybdenum. Total ore reserves of these additional projects are:

| | million metric tons | $ million |
|---|---|---|
| Mount Emmon | 160 | - |
| Thompson Creek | 181.4 | 300 |
| Nye County | 136 | 200 |
| Mount Tolman | 900 | 500 |
| Quartz Hill | 635 | 400 |
| | 2,012.4 | 1,400 |

$$\frac{2{,}012.4}{15{,}911.05} = 12.6\%$$

of the reserves are tapped. The amount invested is over

$1.4 billion not counting the Mount Emmons project which lies very far in the future.

In other words, the U.S.A. will continue to be the world molybdenum supplier Number One. As a matter of fact, it is so rich that molybdenum has not been placed among the metals on the new $15 billion order list to replenish the strategic stockpile of the United States.[21]

Chile

In Chile, Codelco is building a molybdenum roaster to produce 12,000 metric tons annually. This investment will be $14.5 million.[22] In the same country which presently undergoes the latest economic miracle of the 20th century under the 'visible hand' of Milton Friedman, the molybdenum production of the famous El Teniente, Chile's second largest copper mine, will expand from 2,800 metric tons per year to 4,850 metric tons by the year 2005.[23] Here, molybdenum is a by-product of copper. The investment cost of this copper-cum-molybdenum expansion is about $734 million until the year 1986, and it is estimated to reach a total of $1.5 billion when completed. The following annual production quantities and ore grades are foreseen.

| Year | Estimated output in metric tons | molybdenum ore grade % |
|---|---|---|
| 1981 | 2,770 | 0.023 |
| 1982 | 2,760 | 0.023 |
| 1983 | 2,740 | 0.023 |
| 1984 | 2,740 | 0.023 |
| 1985 | 2,720 | 0.023 |
| 1986-90 | 3,612 | 0.021 |
| 1991-95 | 4,152 | 0.021 |
| 1996-2000 | 4,274 | 0.021 |
| 2001-2005 | 4,866 | 0.0225 |

Source: see 24.

This means that, by the end of this century, the Chilean molybdenum production will have increased by 11.1 percent over the output of 13,500 metric tons by the operation of this mine alone. By the year 2005, the production capacity will have gone up by 15.4 percent. However, the breakdown also shows that in the immediate future, El Teniente's molybdenum output will remain stationary; as a matter of fact, it will tend to decline slightly until 1985.

Mexico

In Mexico, the Minero Frisco Company is planning an open-pit molybdenum mine at Cumobabi, Sonora. This mine is to produce 2,000 metric tons of ore per day, or, at least 500,000 metric tons per year. This is an expansion of Mexico's first molybdenum mine which started in the middle of the year 1980 and which is aiming at a total output of 2,000,000 metric tons of ore annually.

The capital cost is in the $23 million range. There is no doubt that this mine will at least yield 2,000 metric tons of molybdenum metal per annum, assuming the conventional ore grade of 0.1 percent. Given the geological affinity of Mexico to other molybdenum-producing areas of the Americas and the known reserve holdings of 1.6 to 2.0 percent of the world, this estimated output of 2,000 metric tons[25] in the year 1980 would represent a more appropriate production figure than the 48 metric tons, or 0.035 percent of world output as recorded for the year 1979. However, it is also possible that in the 1990s, Mexico must contemplate raising its production even further to keep pace with the developments on the molybdenum scene in other countries.[26]

U.S.S.R.

Understandably, it is difficult to obtain a realistic picture of the molybdenum reserves of the Soviet Union. According to one report, the estimated reserves are 200,000 metric tons.[27] They might be called the short-run reserves. If one takes Kuklis' figures as relevant, Russia's long-run reserves might run up to 5 billion pounds or 2.267 million metric tons, a long-run reserve figure which is eleven times larger than the short-run value.[28] Duncan Derry, in turn, places the total at 400,000 metric tons.[29] Since this study tries to look far into the future, it would appear reasonable to adopt the so-called 'long-run' figure of 2.267 million tons as appropriate for this analysis.

The molybdenum production of the U.S.S.R. has always been substantial but it has never reached the height of Canadian output. The following breakdown indicates roughly the performance of the Russian molybdenum industry.

| Year | Molybdenum output in metric tons | percentage change over previous period |
|---|---|---|
| 1975 | 9,060 | |
| 1976 | 9,350 | 3.2 |
| 1977 | 9,700 | 3.74 |
| 1978 | 9,900 | 2.06 |
| 1979 | 10,200 | 3.03 |

Source: see 30

This breakdown illustrates the molybdenum produced and the annual rate of change for five consecutive years. The average rate of increase for these five years was, at best, 3.1 percent. The question arises, in which types of ores this output is found. In essence, there are three different types of ores: 50 percent of the metal comes from molybdenum-copper ores; 30 percent stems from molybdenum-tungsten ores and only 20 percent are refined from molybdenite.

The molybdenum-copper deposits are in Armenia, Kazakhstan, Sorskoye and in Siberia. Strishkov also reports that the tungsten-molybdenum ores are located in Tyrny-Auz of the Kabardin, A.S.S.R. in the North Caucasus and in Dzhida of the Buryat A.S.S.R. The molybdenite ore is found in Usbekistan and in Siberia. This reference also mentions that there are another 100 molybdenum

deposits in the Ural Mountains which are uneconomic for mining due to their smallness.

In addition, there is a copper-molybdenum complex in Mongolia, the Erdenet Complex. Concentrates from this plant which was completed in the year 1979, are shipped to the U.S.S.R. for refining. The quality of the copper ore is reported to be 1.0 percent whereas the molybdenum grade is a mere 0.02 percent. The size of the deposit is not given in this reference.[31]

The same reports also specify the importance of molybdenum to the economy of the U.S.S.R. Bent towards rapid and high-technology industrialization, the U.S.S.R. needs molybdenum very urgently. It may have plenty of substitutes such as chromium,[32] tantanlum, vanadium[33] and cadmium, but there are two metals used in the production of alloys in which the U.S.S.R. is definitely not self-sufficient. One is tungsten, for which it has to rely for 12 percent of its consumption on imports from China and Mongolia; the other is molybdenum, for which the U.S.S.R. has to depend for at least 15 percent on the supplies from the United States and Canada. Therefore, the United States and Canada help to satisfy the molybdenum consumption needs of the Soviet Union.

China

China is at the crossroad of high-technology industrialization. This includes the mining industry to a very important

degree. K.P. Wang writes:

> The Ministry of Geology is systematically adopting aerial prospecting, remote sensing, advanced geophysical and geochemical prospecting, advanced probing and drill equipment, and increased computerization to modernize the geological work.[34]

This means that China is moving quickly towards the development of a huge and modern mining industry. It should not be forgotten that China is not only a country of a high culture, but in many industrial areas it is ahead of many of the so-called developing nations of Africa and America. Chinese construction, manufacturing and mining are industries in point. There is already a workforce which is quite familiar with all facets of machinery and mechanization. Wang also points out that China has a large and diligent workforce, of which a substantial number of people are involved in mineral research. He reports a total geological workforce of 400,000, including 60,000 professionals and 6,000 specialists with substantial support in this research endeavour emanating from numerous geological schools and colleges.[35] Research institutes, and even factories assist in exploration and geological work.

China is a country which is very familiar with medium-sized mining operations. If something is lacking, then it is the "large scale facilities, integrated operations systems, and computerization in the overall area of mineral extraction."[36]

Having finally opened again the doors to the world, a billion people are anxiously waiting to avail themselves of the

opportunities which lie in their own human and mineral resources complemented by foreign capital infusion and technology transfers.

The signs are there already. As Wang reports: Minister Sun Daguang of the Ministry of Geology, in an information interview, stated that China's "deposits of 17 minerals...are among the largest in the world, if not the largest."[37] One of the 17 minerals quoted is molybdenum. Unfortunately, the magnitude of these deposits have not been revealed, but it is important to realize that, consequently, the values underlying the distribution of Table 5 would be substantial underestimates. These distribution figures would, therefore, be wrong, if the Chinese deposits are as large as claimed. This only shows again how fragile the ground on which all resource arguments stand.

The molybdenum resources in China are of three varieties: 73 percent are based on the porphyry types, 13 percent come as by-products from polymetallic ores and 11 percent are found as "contact replacement skarns."[39]

Evidently, at least two American firms should be quite familiar with the Chinese molybdenum potential. One is the Fluor Corporation which is developing the large copper-molybdenum deposits in the Jiangxi Province.[40] The other is no minor than the world's largest molybdenum producer: AMAX. Wang reports that in 1978 and 1979, top executives from AMAX had frequently

visited China and it can be assumed that they must have examined China's molybdenum deposits and potential.[41]

What then is the future of China in the world molybdenum market? Wang provided some type of an answer to this question, although he gives two different versions. The difference between the two references of his arises in that he omits one important sentence in one of his two almost identical articles but presents it in the other.[42]

> There are signs, therefore, that China could become a substantial producer of molybdenum a decade from now, with sufficient supplies not only to meet domestic needs of the metallurgical industry, but also to provide some surpluses for sales abroad.

This is the end of the quotation of one source.[43] The other continues:

> Recently, Chinese concentrates of 45% grade molybdenum have been offered for sale in the U.S. markets.[44]

Does this mean that China is much closer to supplying molybdenum to the rest of the world than we are inclined to think and that the Chinese will be very active participants in the molybdenum markets?! There is, of course, no answer to this question.

However, this is not to imply that, then, China will be out to threaten the world market by destabilizing world molybdenum prices. Any speculative thought in this direction is out of place - and whatever the famous Chinese proverb applicable for this case - it does not reflect the reality of Chinese salesmanship nor the theoretical conditions of a stable oligopoly price should this particular market structure be relevant for molybdenum.

## SECTION V: THE FUTURE OF MOLYBDENUM

Initially, this section shall briefly review the history of past prices until 1979 and then it will study the econometric forecast of prices until the year 2004; finally, the view will be directed to future output and consumption.

### Prices

#### Historical Prices

Of the various molybdenum prices, such as the prices for calcium molybdate, molybdic oxide, ferro-molybdenum and metal powder, different time series could be obtained. In this summary, however, the most important type of molybdenum suitable for description and analysis is the price of molybdenum concentrate per pound of $MoS_2$.

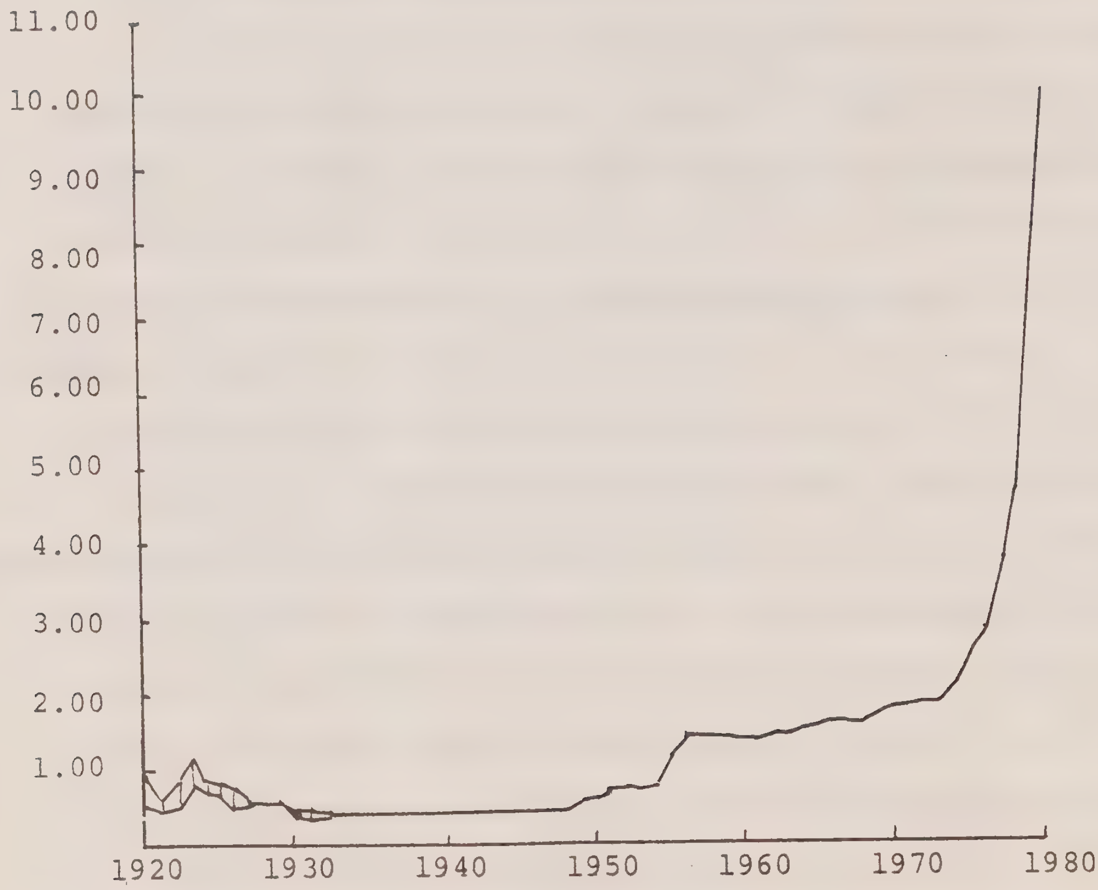
As Table 6 and Exhibit 1 demonstrate, the price behaviour of molybdenum in the past was one of great relative stability, at least until the critical year 1974. During the period from 1920 to 1926, the price seemed to have varied within the range of 48¢/lb and $1.05/lb with a high accomplished during 1923. In the early years of the depression, the price slid to 35¢/lb, the lowest quotation of the time. In the year 1932, it was already back up to 42¢/lb and in 1933, it stood at 45¢/lb, where it remained unchanged for a full 15 year period. Only in 1938 did

the price give in temporarily when it moved to 42¢/lb. During the year of 1949, it rose to 54¢/lb, starting a steady and stable incline, to be interrupted only once, viz. when, in 1955, it shot above the $1.-/lb mark. Afterwards, the price continued its steady rise until the year 1973, finishing at $1.72/lb; this was before the big take-off was to take place.

In the following year, it broke through the $2.- barrier and, with increasing strides, jumped to $3.71/lb in 1977. By 1979, the price more than doubled from that recorded in 1977, reaching $4.59/lb in 1978 and $7.76/lb in 1979. By the year 1980, it averaged about $9.88/lb. The interesting part of this price performance is that it stands quite in contrast to the way in which the prices of most metals operate. Molybdenum has, generally, been a producer-determined price posted for a specific product - Climax cans.[45] This stability was particularly noticeable on a monthly comparison and means that, similar to nickel at one time, no real competitive market existed. In the same sense as the International Nickel Company was the price-leader (nickel), this role is exercised by the AMAX Corporation - the owner of the Climax Mine - which carefully announces the price for molybdenum. With a steadily rising strong demand and under persistently increasing inflationary price and cost pressures, it is not at all surprising to see this phenomenal price hike. However, the subsequent increase for 1980 was not as strong as had been the case for the years 1978 and, especially, for

Exhibit 1

Molybdenum Prices in Current U.S. Dollar per pound of
Molybdenum Concentrate for the Years 1920 to 1980




Source: Table 6, p.39.

Table 6

Molybdenum Prices (concentrates per pound of molybdenum)

in Current U.S. Dollars for the Years 1920 to 1980

| Year | $/lb | Year | $/lb |
|---|---|---|---|
| 1920 | 0.55-0.85 | 1950 | 0.54 |
| 1921 | 0.45-0.60 | 1951 | 0.60 |
| 1922 | 0.45-0.80 | 1952 | 0.60 |
| 1923 | 0.75-1.05 | 1953 | 0.60 |
| 1924 | 0.65-0.80 | 1954 | 0.64 |
| 1925 | 0.65-0.70 | 1955 | 1.05 |
| 1926 | 0.48-0.70 | 1956 | 1.16 |
| 1927 | 0.48-0.50 | 1957 | 1.21 |
| 1928 | not available | 1958 | 1.21 |
| 1929 | not available | 1959 | 1.25 |
| 1930 | 0.35-0.55 | 1960 | 1.25 |
| 1931 | 0.35-0.45 | 1961 | 1.35 |
| 1932 | 0.42-0.45 | 1962 | 1.40 |
| 1933 | 0.45 | 1963 | 1.40 |
| 1934 | 0.45 | 1964 | 1.51 |
| 1935 | 0.45 | 1965 | 1.55 |
| 1936 | 0.45 | 1966 | 1.55 |
| 1937 | 0.45 | 1967 | 1.61 |
| 1938 | 0.42-0.48 | 1968 | 1.62½ |
| 1939 | 0.45 | 1969 | 1.69 |
| 1940 | 0.48 | 1970 | 1.72 |
| 1941 | 0.45 | 1971 | 1.72 |
| 1942 | 0.45 | 1972 | 1.72 |
| 1943 | 0.45 | 1973 | 1.72 |
| 1944 | 0.45 | 1974 | 2.02 |
| 1945 | 0.45 | 1975 | 2.49 |
| 1946 | 0.45 | 1976 | 2.71 |
| 1947 | 0.45 | 1977 | 3.71 |
| 1948 | 0.54 | 1978 | 4.59 |
| 1949 | 0.54 | 1979 | 7.76 |
| | | 1980 | 9.88 |

Source: Schneider, ibid., p. 121, Table 19; for the years 1920-1949; Engineering and Mining Journal, 1950 to 1980, annual monthly averages.

1979 which had been marred by severe labour problems in Canadian molybdenum mining. Also, at the end of 1980, the prices even started to slide somewhat to finish at $9.70/lb.

Future Prices

Subject to the reservations stated by the authors regarding the assumptions underlying the econometric model in connection with gold, lead and zinc, a certain picture was obtained predicting the behaviour of molybdenum prices. The price of this metal expressed in constant 1979 U.S. dollars is not expected to increase substantially until the year 1983.[46] As can be seen in Table 7 and Exhibit 2, it will only be in 1984 that it will exceed $10.-/lb and only in the following years will it move higher and that at an increasing rate. Due to the stepped-up consumption demand for this exceptional metal, the forecast envisages a price of $37.12/lb of molybdenum by the year 2000. Four years later, the mathematical model tells us that a pound of this substance would cost $52.86/lb.

It would appear that such an optimistic forecast is difficult to justify, especially when expressed on constant dollars. The authors firmly believe in the price predictions for the five years until 1985; as to the following five-year period, they find themselves reasonably convinced that the events to come will confirm the prediction. However, beyond 1990, this strength

Exhibit 2

Molybdenum Prices (concentrates per pound of MoS2) in Constant 1979 U.S. Dollars for the Years 1980 to 2004

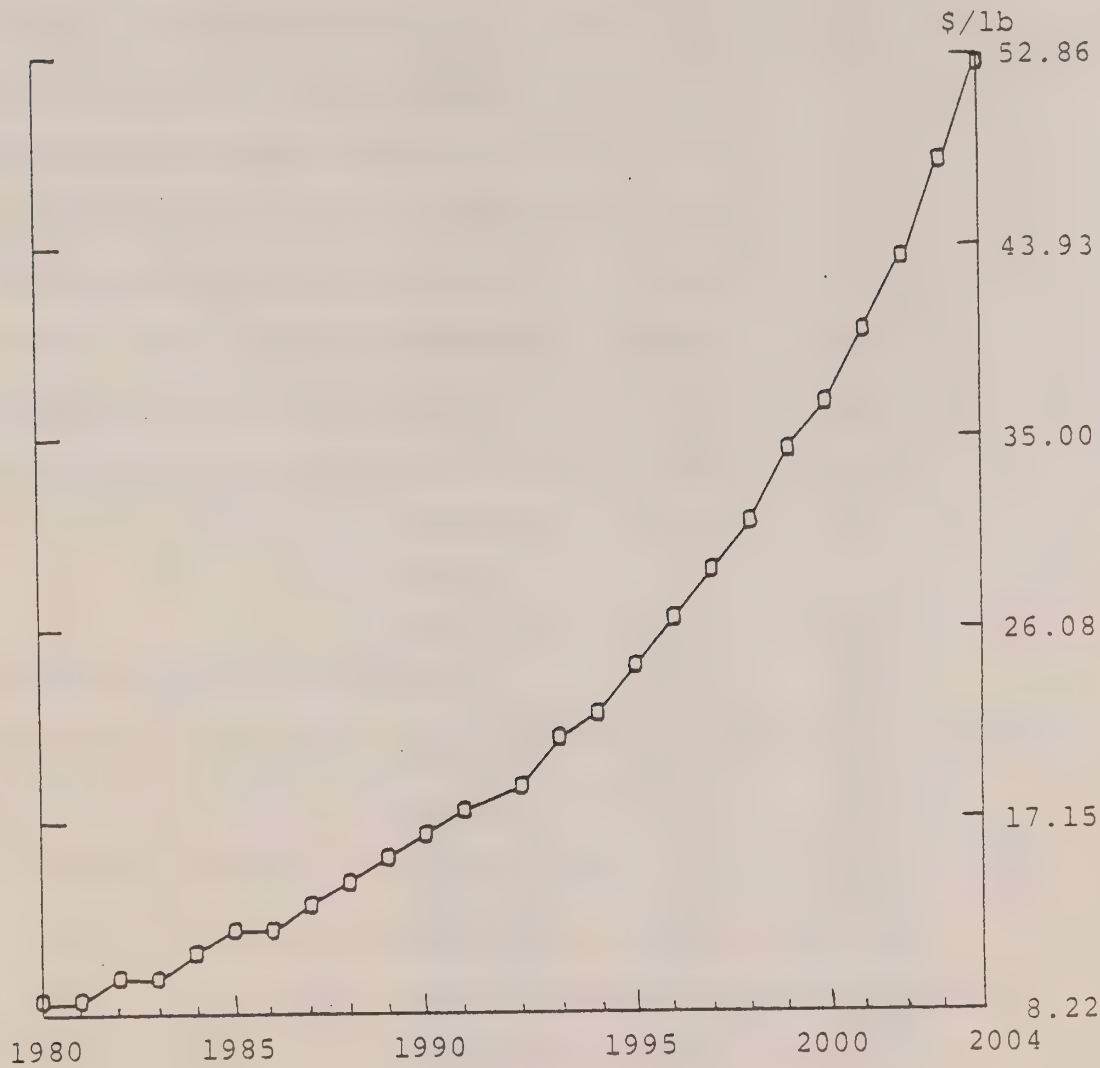


Table 7

Molybdenum Prices in Constant 1979 $ U.S./lb and Production

in metric tons for the Years 1980 to 2004

| Years | Prices | Production |
|---|---|---|
| 1980 | 8.22 | 106,725 |
| 1981 | 8.72 | 110,427 |
| 1982 | 9.27 | 114,191 |
| 1983 | 9.88 | 118,031 |
| 1984 | 10.55 | 121,965 |
| 1985 | 11.29 | 126,008 |
| 1986 | 12.10 | 130,175 |
| 1987 | 13.00 | 134,484 |
| 1988 | 13.98 | 138,948 |
| 1989 | 15.06 | 143,584 |
| 1990 | 16.25 | 148,407 |
| 1991 | 17.56 | 153,431 |
| 1992 | 19.01 | 158,672 |
| 1993 | 20.59 | 164,145 |
| 1994 | 22.33 | 169,866 |
| 1995 | 24.25 | 175,849 |
| 1996 | 26.36 | 182,111 |
| 1997 | 28.68 | 188,666 |
| 1998 | 31.23 | 195,532 |
| 1999 | 34.04 | 202,725 |
| 2000 | 37.12 | 210,262 |
| 2001 | 40.51 | 218,160 |
| 2002 | 44.25 | 226,436 |
| 2003 | 48.35 | 235,109 |
| 2004 | 52.86 | 244,198 |

Source: Econometric Analysis.
See Ch. I.

of conviction, understandably, starts to wane and for the period beyond 1995, it would be unreasonable to insist that this forecast will prove to be true.

In retrospect for the prediction made for the year 1980, the value came out to be very close to the truth. It has also to be born in mind that the cost of producing any future output will be rising. It must rise on this account because leaner ores will be extracted, more expensive capital and labour will have to be employed, more expensive energy will have to be used and resources will have to be tapped which are less accessible and far removed from markets. These cost components include, at the same time, that very important factor called rent which is quite considerable for molybdenum. It will be upheld unless competition enters the field and starts to erode the rent component.

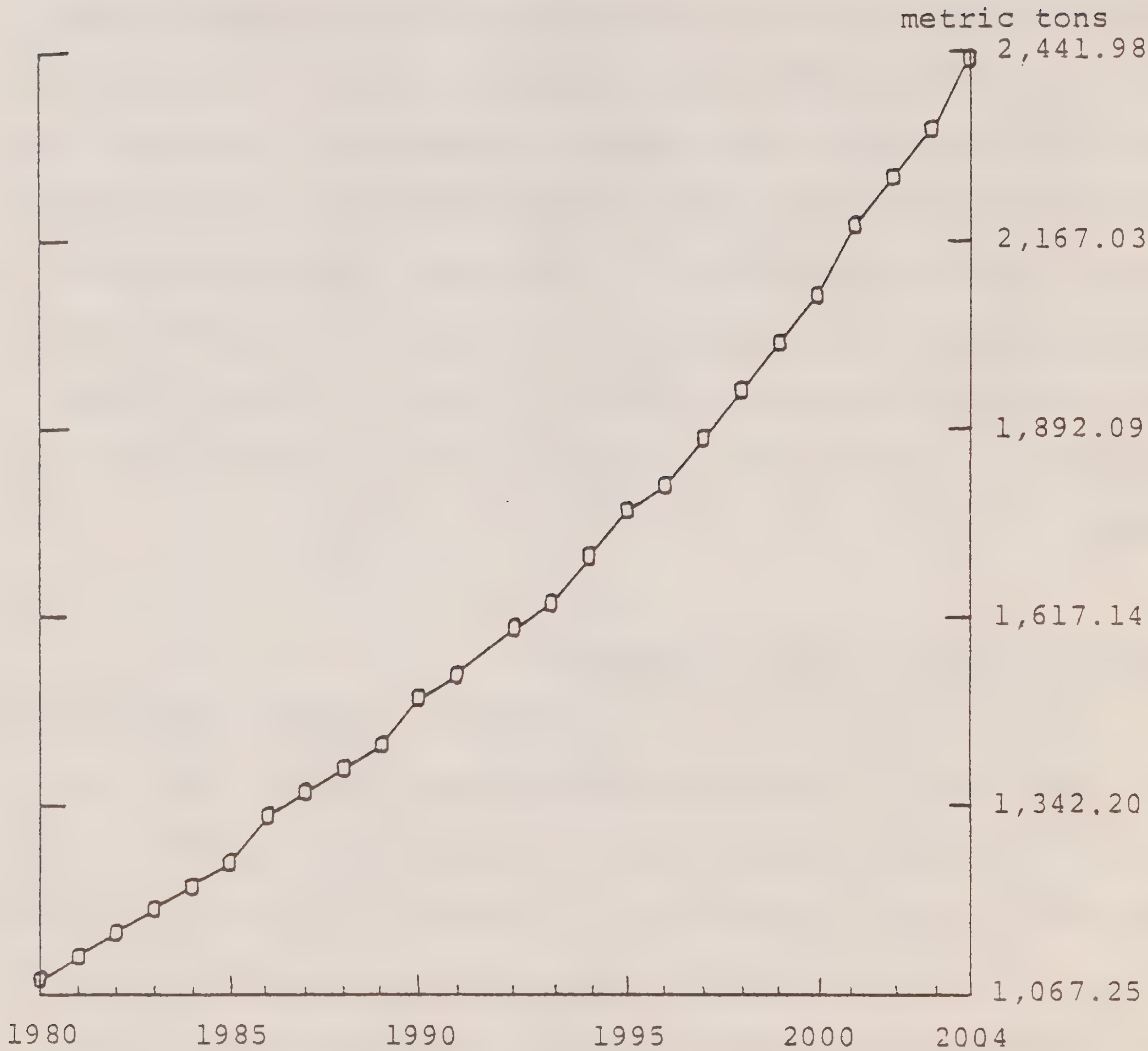
## Future Production and Consumption

According to Exhibit 3 and Table 7, molybdenum production will experience a substantial rise in the future. From an actually observed output of 103,066 metric tons in 1979, molybdenum mine output is predicted to rise to 106,725 metric tons for the year 1980. In retrospect, the forecasting model performed well considering that observed world production was 105,078 metric tons underperforming by an error of -1.54 percent.[47]

Exhibit 3

World Production of Molybdenum for the Years 1980 to 2004

in metric tons



Until the year 2004, this forecast envisages a total increase to annual output by 137 percent, rising to 244,198 metric tons as shown in Table 7 and illustrated in Exhibit 3. Admittedly, that is a relatively small rate of growth compared to the spectacular expansion which took place in the period between 1950 and 1979. Production, then, rose from 14,230 metric tons to 103,066 or roughly by over 600 percent. Now, the forecast up to the year 2000 envisages merely a doubling of output over that of the year 1979, meaning that the relative change is comparatively small although the absolute quantities are huge!

The question may easily be raised as to how well this forecast compares to other predictions? The answer may be found in the following breakdown which gives the values of molybdenum production predicted for selected years by two other expert sources.

| Year | Dr. Willauer[1] L.U. | Sutulov[2] total | Sutulov[2] from new mines | Kuklis[3] U.S.B.M. |
|---|---|---|---|---|
| 1980 | 106,725 | 111,000 | 550 | ------- |
| 1981 | 110,427 | 122,000 | 8,620 | ------- |
| 1982 | 114,191 | 129,000 | 17,130 | ------- |
| 1983 | 118,031 | 140,500 | 28,130 | ------- |
| 1984 | 121,965 | 152,000 | 38,290 | ------- |
| 1985 | 126,008 | 161,000 | 44,690 | 138,776 |
| 1986 | 130,175 | 162,600 | 53,240 | ------- |
| 1990 | 148,407 | 198,000 | ------ | ------- |
| 1995 | 175,849 | 235,000 | ------ | ------- |
| 2000 | 210,262 | 275,000 | ------ | 265,760 |

[1]Table 7

[2]Engineering and Mining Journal, September 1980, p.145

[3]Kuklis, ibid., p. 711.

This breakdown permits a comparison between the figures provided by this forecast (Dr. Willauer) and the future world molybdenum production as seen by Sutulov and in 1975, by the U.S.B.M. (Kuklis) for the years 1985 and 2000.

Evidently, the forecast undertaken for this study gives a slower rate of growth of future molybdenum output. For 1985 it is 9.2 percent below that of the U.S.B.M. and 21.7 percent below Sutulov's. This discrepancy is much larger for the year 2000, differing by 19.8 percent from the former and by 23.5 percent from the latter.

However, one could interpret Sutulov's forecast as pertaining to the output which the mines will be capable of producing. Then, his figures are equivalent to a production capacity. Whether it will be necessary to utilize this mining capacity fully remains another unanswerable question. It would be answered in the negative on the base of the present forecast. The exploitation of the available resources would be extended further into the future.

According to this projection, by the year 1985, 0.7 million metric tons of molybdenum will have been cumulatively mined; by 1990, this figure would stand at 1.39 million metric tons. By the year 1995, it would amount to 2.2 million metric tons, 3.2 million by 2000, and eventually, 4.1 million metric tons by the year 2004.

In the light of the available reserves, the year 2004 would have seen the absorption of 42 percent of the 9.8 million metric tons - the short-run reserves. When measured against the long-run reserves of the U.S.B.M., only 14 percent of the world molybdenum reserves would have been taken out of the ground.

## SUMMARY AND CONCLUSION

Molybdenum is a very important metal in the fields of high technology of modern industrialized societies. During the past thirty years, molybdenum has gained in significance in a variety of end-uses to become the industrial glamour metal which it is today. In the United States, a definitely established use-pattern can be shown to exist which hardly changed over at least the last two decades. In other highly industrialized countries, no essential difference in these use patterns is noticeable. However, if anything has changed during this period, then, it is the sheer volume of molybdenum consumption.

Between 1950 and 1979, recorded world production rose by 624 percent, or roughly by over seven times its initial production. For Canada, this performance was much more pronounced because between 1951 and the peak year 1977, output of this metal multiplied 157.9 times!! Canada became the second largest producer of molybdenum of the world, followed by Chile and the U.S.S.R. Unfortunately, Ontario had to be left out of the record because its stake in molybdenum production was almost nil.

Canada exports most of its molybdenum ores and concentrates mainly to Belgium, Japan, the United Kingdom, the United States and to Western Germany. However, the U.S.S.R. has also become a Canadian molybdenum customer. However, a certain

quantity of molybdenum returns to the end-user in Canada in a more refined form.

The world's generally known molybdenum reserves are located to about 85 percent in the Americas, with the United States as the single most important reserve holder. On the world scene, Canada follows next ahead of Chile and the U.S.S.R., while Peru and Mexico are other American countries with important molybdenum deposits. In short, there is no shortage of reserves. At present, the main resource holder of this metal is the United States, which experiences substantial investment activities to secure future molybdenum supplies. Understandably, the United States is in the forefront of all countries by having committed almost $2 billion to the mining of this miracle metal. Of course, other firms in Chile and Mexico, to name just two, are not idle. There, likewise, large amounts are poured into the opening-up of molybdenum orebodies. The United States, therefore, is the main molybdenum supplier of the world and will remain in this position for years to come, provided no unforeseen events will interfer with this situation!

These unforeseen occurrences are not expected to come from the U.S.S.R. which is very much strapped for molybdenum supplies as it consumes more than it produces. As a matter of fact, the U.S.S.R. is to 15 percent dependent on molybdenum imports from the U.S.A. with Canada adding its own small contribution. The

change may be caused by another country: China. It stands presently in the background with an estimated molybdenum output of 1000 metric tons. However, this country is reported to have made huge molybdenum discoveries enabling China, within a decade, to emerge as a significant net exporter of this metal; this is the possible cloud overshadowing the present molybdenum landscape.

Following the econometric analysis, molybdenum prices ought to continue their spectacular climb over the next ten years. To accept the suggested price developments beyond the year 1990 does not appear reasonable! The future world output, as determined in the same econometric analysis, indicates a slower rate of growth than prevailed in the base period from 1950 to 1979. This projection is less enthusiastic than those made by other experts in the field.

It is recognized that there are plenty of world molybdenum reserves such that the total volume of expected extraction does not seem to endanger the long-run supply of the metal. It should last very far into the next century.

The conclusion can, therefore, be drawn that there will be no shortage of the metal due to relatively high-grade ores, existing in large quantities and the amounts of investment funds allocated to the mining of this very important and interesting metal. Unless substantial high-grade reserves could be

ascertained in Ontario - an unlikely event due to a geological structure which differs from the normal porphyry-type molybdenum-bearing rocks - Ontario will remain on the sideline in this respect. Canada, however, will continue to be the second largest molybdenum producer, procuring the other industrialized countries with its molybdenum ores and concentrates. Due to the expected phenomenal expansion in mining capacities, extreme and long-run shortages are unlikely to materialize. However, any excess in supply over consumption needs may quite easily, even though only temporarily, disrupt the steady upward movement of molybdenum prices and force prices to fluctuate around a trend which formerly had a greater stability in the form of posted prices. Close observation and management of production in the light of relevant inventories and stocks of the metal in the world may assure continuity of past price behaviour. However, since the market supply may not always remain in the hands of a definite number of companies and countries, as molybdenum mining is concentrated in the United States, Canada and Chile, the relative certainty of expected prices for this metal may not necessarily be as self-understood after 1990 than they were from the 1930s to the late 1970s. Let it not be forgotten that China could become one of the world's largest suppliers of molybdenum, due to its alleged new resource potential; this is a 'maybe', not a 'must'.

NOTES

1 Scientific symbol is Mo; atomic weight 96.0; specific gravity 9.01; melting point 4730°F; occurrence 2.50 ppm.

2 This is a summary of uses given in the following references: Andrew Kuklis, "Molybdenum", U.S.B.M. op. cit., pp. 699-713; Alexander Sutulov, "Supply-Side Prospects for Molybdenum", Engineering and Mining Journal, September, 1980, p. 141; Albert Mari, "Molybdenum Profile," Metal Statistics, 1979, American Metal Market, p. 141; W.F. Distler, (a) "Molybdenum", M.A.R., op. cit., 1980, pp. 89-92;------, (b) "Molybdenum Outlook Remains Good as New Mine Properties are sought," Engineering and Mining Journal, March 1980, pp. 99-103; (c)------, "Molybdenum Demand dips Below Recent Years As Output Continues to Climb," Engineering and Mining Journal, March 1981, pp. 108-111.

3 Wallace Macgregor, "Molybdenum," Engineering and Mining Journal, vol. 164, No. 2, February, 1963, p. 137.

4 Distler, ibid., (b), p. 100.

5 For the distribution of consumption given by Distler, see: M.A.R., ibid., p. 91.

| | 1976 | 1977 | 1978 | 1979 | *) Consumption by Area in million of pounds |
|---|---|---|---|---|---|
| United States | 57 | 60 | 69 | 71 | |
| Western Europe | 70 | 70 | 72 | 75 | |
| Eastern Block | 15 | 17 | 22 | 22 | |
| Japan | 25 | 24 | 25 | 25 | |
| Other | 10 | 11 | 12 | 12 | |
| Total | 177 | 182 | 198 | 205 | |

6 Since 1977, such voluntary supply allocation systems were in operation supported by tariff remissions on Canadian molybdenum reimported in the form of molybdic oxides. Cf. A.J. Webb, "Molybdenum", adv. Bulletin, Canadian Minerals Yearbook, 1979, Ottawa, 980(?

7 A strike took place at Endako Mines, operated by Placer Development, lasting from February 15 until November 1, 1979, and at Brenda Mines, a subsidiary of Noranda Mines Limited; this strike started on September 14 and lasted exactly one month. See Distler, loc. cit. (a), p. 99.

8 Canada produced molybdenum ores and concentrates as early as 1914 when 0.9 metric tons were mined. By 1918, it reached 102.9 metric tons. Afterwards, production stopped for several years until 1924, when about five metric tons were produced. In the following years, production was highly sporadic and it was only in 1941 when molybdenum output started to flow on a continuous basis. See V.B. Schneider, Molybdenum, Mineral Resources Divison, Department of Mines and Technical Surveys, Ottawa, Mineral Report 6, Queen's Printer, Ottawa, 1963, Table 4, pp. 106-107. This source also traces world production from 1905 onward. Before that year, a total of 272 metric tons had been mined in the world. For a glimpse at the history of the development of molybdenum in Canada, the economic historian could find an inspiring source in Appendix III of the same study "Chronology of the Canadian Molybdenum Mining Industry," ibid., pp. 137-147.

9 n.7. supra.

10 See F.J. Johnston, Molybdenum Deposits in Ontario, Ontario Department of Mines, Mineral Resources Circular No. 7, 1968; cf. V.B. Schneider, op. cit., pp. 152-154; and R.C. Annis, D.A. Cranstone and M. Vallee, A Survey of Known Mineral Deposits in Canada that are not being mined, Ministry of Energy, Mines and Resources, Ottawa, April 1978.

11 F.J. Johnston, ibid., p. 2 (Table).

12 Schneider, ibid., p. 109, Table 6.

13 Technical Information Paper No. 2, Table 5, p. 9-10.

14 Michael Boucher, "Molybdenum," Canadian Minerals Year Book, 1977, Ottawa, p. 287. For earlier years - 1935-1961 - see Schneider, op. cit., p. 108, Table 5, esp. n.6; also see A.J. Webb, loc. cit., p. 3.

15 Schneider, ibid.

16 M.G. Fleming, op. cit., xviii; see also: Report on Zinc, Chap. XI.

17 See Kuklis, loc. cit., p. 700.

18 Distler, op. cit., (a), p. 91.

19 Engineering and Mining Journal, March 1981, p. 73.

20 "Amax signs record tribal pact at Mt. Tolman," Engineering and Mining Journal, ibid., p. 48, 55. The Indian tribe shares 50% in the net revenues of the mine after a 3-4 year capital recovery period, during which the return to the tribe will be $1 million per annum. Thereafter, the expected return to the tribe will be $50 million per annum, or $1 billion over the life of the mine - tax free! Six hundred jobs will be created at an annual payroll of $12 million.

21 "U.S. strategic minerals stockpile to be revamped by new Administration," Engineering and Mining Journal, April 1981, p. 11.

22 Engineering and Mining Journal, ibid., supra, n. 19.

23 "Expansion will make El Teniente Chile's largest producer by 1995," Engineering and Mining Journal, March 1981, p. 39, 43.

24 Ibid.

25 This coincides with Distler, loc. cit., (n.2. supra)(c), p. 111, Table (4,000,000 pounds for 1980).

26 The same point applies to Peru which produced about 1,183 metric tons of molybdenum in 1979 and which has double the known resources of Mexico; this case cannot be made for the Philippines whose resources are much smaller.

27 a) IMMR, 1980, pp. 185-186; cf. the almost identical wording in (b) M.A.R., 1980, p. 599 and written by the same author: V.V. Strishkov, U.S. Department of Mines.

28 Kuklis, loc. cit., p. 703 (Table).

29 Duncan Derry, ibid.

30 Strishkov, ibid., a) p. 207, b) p. 594.

31 Ibid., b) p. 599.

32 The U.S.S.R. is to 40 percent "export-dependent" as concerns chromium reproduction.

33 Export dependency is 5 percent.

34 K.P. Wang, "China," M.A.R., 1980, op. cit., p. 436.

35 Ibid., p. 436.

36 Ibid., p. 435.

37 Ibid.

38 No purpose is served in discussing in detail the molybdenum geology of China. The reader has to be referred to Wang's discussion of China's molybdenum deposits, however inconclusive that discussion, unfortunately, is: ibid., p. 448.

39 Ibid.

40 Ibid., Cu: 0.4% - 0.5%; Mo: 0.03% - 0.08%.

41 Ibid.

42 One source is, of course, a) ibid.; the other is the customary parallel article b) K.P. Wang, "China," IMMR, 1980, op. cit., pp. 483-517; esp. p. 504.

43 Ibid., b).

44 Ibid., a).

45 Normally: lb. cont. Mo., c.i.f. U.S. ports, Climax oxide, cans. See Technical Information Paper No. 1.

46 This is born out already, at least to some degree, by the recent current prices of molybdenum of $9.35/lb.

47 Distler, loc. cit., (c), pp. 108-109 has the preliminary output of the non-communist world of 93,878 metric tons. Adding the estimated quantity of production of 10,200 metric tons for the U.S.S.R. and 1,000 metric tons for China, the preliminary output for 1980 is 105,078 metric tons. Sutulov's forecast has a negative error of -5.34 percent, i.e. the difference between 111,000 and 105,078, in percent.

# APPENDIX

MOLYBDENUM MINES

| Operating Mines | Mines under Development | Existing By-Product Mines Copper Molybdenum |
|---|---|---|
| Climax | Goat Hill | Ajo |
| Henderson | Thompson(by-prod.) | Tyrone |
| Sierrita | Mt.Tolman | Granisle |
| Chuquicamata | Mt. Pleasant | Bougainville |
| El Teniente | Highmont | |
| Utah Copper | | |
| San Manuel | Los Broncos (Chile,Exxon) | |
| Lornex | Frisco (Mexico) | |
| | La Caridad (Mexico) | |
| | Cuajone(Peru ) | |

New Generation of Mines[1)]
(Molybdenum and copper-Molybdenum Deposits)

| | |
|---|---|
| Mt. Emmons | Colorado |
| Quarts Hill | Alaska |
| Adanac | Canada |
| Quebrada Blanca | Chile |
| Los Pelambres | Chile |
| Cerro Colorado | Panama |
| El Pachon | Argentina |

1) These mines require a 10 % annual growth rate of consumption to be economically feasible.

On the Canadian scene, two mines in the west have taken the spot light:Brenda Mines, a subsidiary of Noranda, and Endako,operated by Placer, are the larger of the operating mines.Of these, Placer is presently investigating the comparatively small molybdenum pr0-perty of Adanac.In short, there are about a dozen new molybdenum sites being opened up; and one of these is the high controversial open-pit mine at Kitsault,British Columbia.This mine is run by AMAX.The ore reserve is 105 million metric tons, with the

high grade of 0.192 % of $MoS_2$.The expected ore capacity will be in the neighbourhood of 10,000 metric tons perday.This mine and its concentrator have been built at a cost of $ 145 million. The mine has begun operations under the strong protest of environmentalists. In addition, Noranada Mines will add a mine with a capacity of 3,000 tons per day at Boss Mountain, also in British Columbia.This mine is to start in 1982 at a cost of $ 12.5 million.